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14. ABSTRACT

The purpose of this Idea Development award is to evaluate the additive benefits of "automated feedback" and eye tracking to "standard" (human-directed training) of driving skills for those who are diagnosed with high functioning autism and have a learner's permit. The goal for year 1, which began when funding arrived on Sept 30, 2012, was to secure and operationalize the software to provide automated feedback and to recruit and train 20 drivers, 10 receiving standard training and 10 receiving automated feedback training at each site. During year 1, we focused on developing automated feedback, which involved creating computer-generated instruction informing drivers when their driving performance exceeded established thresholds for different driving parameters, e.g. the simulator says "Speeding" when the driver exceeds the posted speed limit by 5mph. During Year 2 we have recruited 21 subjects to undergo routine training and then receive VRDS training with adjunctive eye-tracking feedback. All of our participants have been able to engage in the driving training, and none have experienced simulation adaptation syndrome. Our current version of automated feedback did not boost efficacy of standard human feedback training, while preliminary analyses suggests eye-tracking feedback may enhance standard training impact.

15. SUBJECT TERMS

Autism, Driving Safety, Driving Simulation, Automated Feedback, Eye Tracking

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INTRODUCTION

Driving a motor vehicle is central to independent living but is a serious responsibility. Symptoms of Autism Spectrum Disorder (ASD) can make the acquisition of driving skills challenging and in some cases even impossible. While some individuals with ASD routinely operate a motor vehicle safely, others do not. Those who do drive typically took three times as long to acquire safe driving skills than the general public. However, there has been no systematic research addressing the questions of which individuals with ASD can learn to safely operate a motor vehicle, and what are good procedures to train adolescents with ASD to safely operate a motor vehicle. This project builds on a prior Department of Defense (DOD) project that demonstrated the feasibility of evaluating and training adolescents with ASD to drive using virtual reality driving simulation (VRDS).

The goals of the current study are to determine if the ability to learn how to safely operate a motor vehicle can be predicted with these simulator tests, whether the ability to benefit from virtual reality driving training can be predicted, and determine an optimal training package to promote the development of safe driving skills for ASD adolescents.

In this project, we aimed to recruit sixty adolescents composed of thirty from Iowa and thirty from Virginia, and evaluated their critical cognitive abilities and initial driving abilities on the simulator. These evaluations, along with an on-road test, were repeated two months later. In between these two evaluations, all of the ASD adolescents proceeded with the routine on-the-road training required by the Department of Motor Vehicles to secure an independent driver's license. Some of these adolescents also received our "standard" training on a virtual reality driving simulator; whereas others received different elements of our virtual reality simulation training. A successful outcome will allow parents and adolescents to know the probability of eventual acquisition of safe driving skills, as well as effective ways to develop safe driving skills.

KEYWORDS

- autism
- autism spectrum disorder
- driving
- driving simulator
- virtual reality driving simulation
- assessment
- training

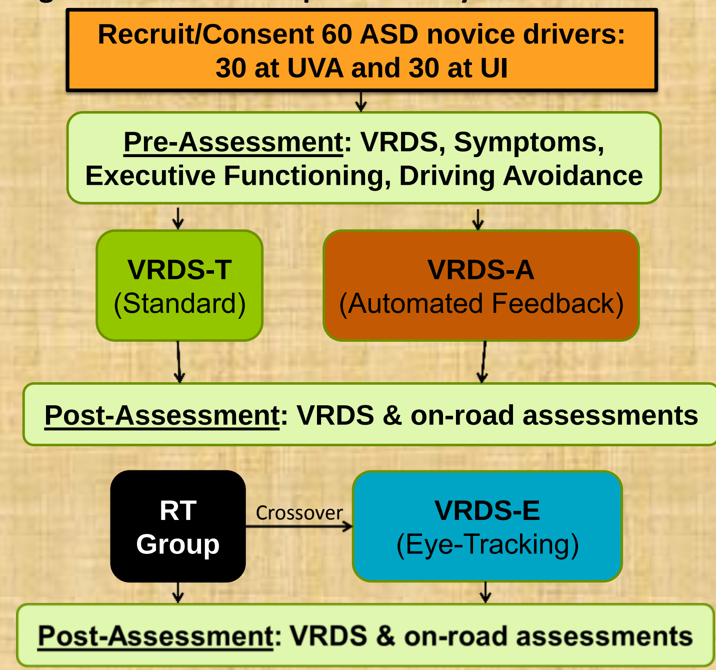
ACCOMPLISHMENTS

What were the major goals of the project?

The goals of the current study were to determine if the ability to learn how to safely operate a motor vehicle could be predicted with these cognitive tests, whether the ability to benefit from

virtual reality driving training could be predicted, and determine an optimal training package to promote the development of safe driving skills for ASD adolescents.

Figure 1. Idea Development Study Flow Chart



What was accomplished under these goals?

We recruited ASD adolescents and young adult subjects who had secured their driving learner's permit but not yet their full license and assigned them to the following groups:

1. Routine driving training (***RT***)
2. Routine (Standard) VRDS training (***VRDS-T***)
3. Routine VRDS training with automated, computer-generated, performance feedback (***VRDS-A***)
4. VRDS training complemented with eye tracking (***VRDS-E***)

We have recruited all subjects and concluded three of the groups. We are now finishing Group #4, VRDS training complemented with eye tracking.

We have also submitted a DoD application for an ASD Randomized Clinical Trial. In that application we included the following findings:

Idea Development Award

This multi-center (U.Va., University of Iowa [**U.I.**]) study was designed to test the following hypotheses: 1) compared to routine driving training (***RT***) required by the DMV, VRDS training + RT (***VRDS-T***) would lead to greater improvement in driving safety and less driving anxiety, 2) VRDS-T augmented with computer-generated automated feedback (***VRDS-A***) would be superior to VRDS-T. Automated feedback involves the simulator detecting in real-time when the trainee's performance exceeds either legal (speed limit) or normative (extent of swerving) guidelines and immediately provides the trainee such feedback (e.g. "You are driving too fast"), 3) eye tracking feedback (***VRDS-E***) would significantly augment either VRDS-T or VRDS-A, whichever was found to be better. VRDS-E involves having the trainee wear Mobile Eye tracking glasses that record eye position to determine where the driver is looking. Playback of this video allows the trainee to view where s/he was looking during any part of the drive and facilitates training where to look if errors exist.
As seen in Figure 1, twenty participants were recruited at each site and then randomized to either ten training sessions of VRDS-T or VRDS-A. Trainees were assessed pre- and post-training in terms of operational and tactical driving performance, driving anxiety, and on-road performance

by an examiner blind to the training conditions (on-road assessment was only performed post-training). Subsequently, ten additional ASD novice drivers were recruited at each site. These participants served as RT controls, with pre- and post-assessment separated by two months. These subjects were crossed over to the VRDS-E condition and evaluated.
Currently, we have recruited all subjects, completed assessments of all VRDS-T, VRDS-A and RT, and have finalized half of our VRDS-E participants.

Preliminary Analyses:

<u>Hypothesis 1 Results</u>: VRDS-T led to significantly better post-assessment tactical composite scores (ANCOVA co-varying baseline performance p= .008). Figure 2 illustrates that at post-assessment, performance with RT was worse than the average of all drivers, while performance with VRDS-T was much better than the average. In terms of on-road performance, more RT participants declined taking the test compared to VRDS-A participants, and more VRDS-T participants passed the on-road test (see Figure 3). In terms of driving anxiety, at post-assessment, SAD scores demonstrated a more positive attitude towards driving following VRDS training (Figure 4).

Figure 2. Outcome of VRDS training program, demonstrating that VRDS-T was superior to RT (p<.01), as was VRDS-A (p<.05), and VRDS-E (p<.05). Training groups were not significantly different.

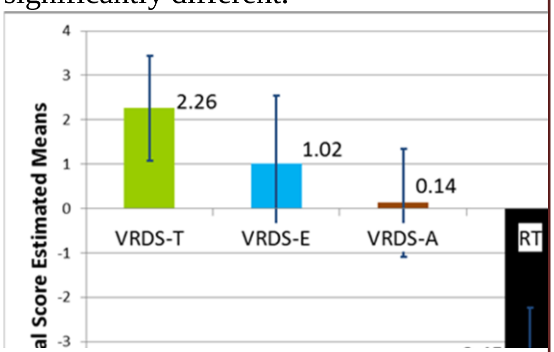
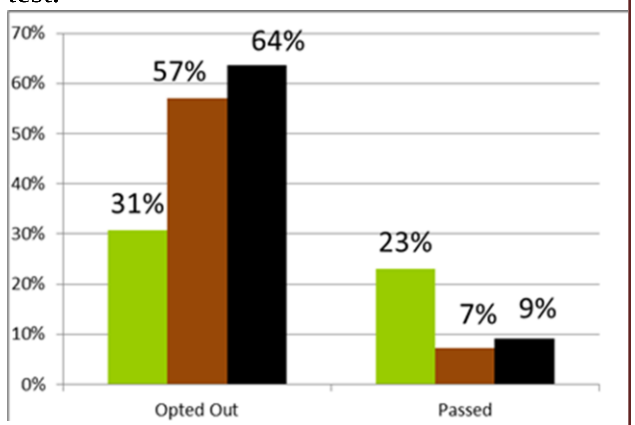


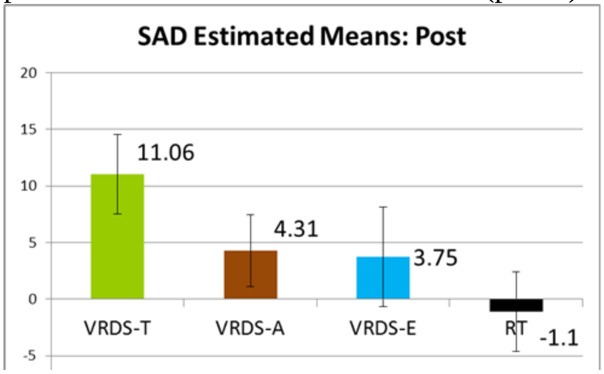
Figure 3. Percentage of participants opting out/refusing to take the on-road tests and percentage that passed the blinded on-road test.



<u>Hypothesis 2 Results</u>: Those receiving VRDS-A were only marginally superior to those receiving RT (p=.059), and automated feedback did not improve VRDS-T (Figure 2).

<u>Hypothesis 3 Results</u>: As seen in Figure 2, after collecting half of the VRDS-E data, it appears that in its current form, required eye-tracking feedback did not significantly enhance efficacy of VRDS-T.

Figure 4. SAD scores were significantly more positive in VRDS-T than in Controls (p=.02).



Discussion

As we have demonstrated with novice drivers without ASD (Cox et al, 2009) and with wounded warriors recovering from TBI, VRDS-T improved driving safety above and beyond RT. We hypothesized that computer-generated feedback would be more palatable than human-generated feedback to those with ASD, but this was not the case. This is probably due to the implementation of the automated feedback being in its infancy. While both trainers and trainees reported that the automated feedback was generally a good idea and useful, the system gave two types of frustrating and misleading feedback: 1) indicating a turn signal was not used when the turn signal had been activated, or indicating a wrong turn when the correct turn had been made, and 2) indicating that the driver was not maintaining lane position when driving on a curvy road, merging onto the highway, avoiding road hazards, or pulling off the road for an emergency. Software modification will correct these issues.

As for the benefits of trainees receiving eye-tracking feedback, preliminary analyses indicate that giving feedback to all subjects on all tactical driving elements does not significantly improve VRDS-T.

From the Idea Development award we learned that VRDS-T can significantly improve the driving safety of novice drivers with ASD, and this is not enhanced by the current version of automated feedback or the routine use of eye-tracking. However, informal feedback from trainees indicates there are some potential benefits derived from some parts of these adjunctive elements for some trainees.

What opportunities for training and professional development has the project provided?

The project was not intended to provide training and professional development opportunities

How were the results disseminated to communities of interest?

We are in data collection, so no results have been professionally disseminated. However, now that we are closed for enrollment, and since our preliminary findings are positive, we have opened up the training to the general public. Appendix 1 displays our clinical flyer. Here is a report we received from our first clinical case:

> Hi Matt –
>
> The driving is going FABULOUSLY! He has moved from just safe loops through quiet neighborhoods to going through town, switching lanes, and managing traffic lights. He even drove into DC today—navigating the GW Parkway, bumper-to-bumper traffic over Roosevelt bridge, and stop-and-go traffic along the Mall to the Museum of Natural History!
>
> Since he is doing so well, I think I'd like to let him do at least some of the driving to Charlottesville on Wednesday. So that I don't get anxious (and pass it along to him) can we shoot for 10:30 as a start time for his next lesson? That way he can stick to the speed limit (or below in some places) and not be late. I'm still debating whether to let him do the first part of the trip during rush hour—he may be able to do it, but I need to get comfortable!
>
> Thanks!

What do you plan to do during the next reporting period to accomplish the goals?

We have been granted a no-cost extension for six months. During this time, we anticipate finalizing data collection and data analysis, along with manuscript submissions.

IMPACT

What was the impact on the development of the principal discipline(s) of the project?

Nothing to report

What was the impact on other disciplines?

Nothing to report

What was the impact on technology transfer?

If we document that our current simulator can assess and train driving competence of those with ASD, then it is reasonable to assume that other simulator companies will develop new

capabilities to enhance this assessment and training, much like Henry Ford stimulated the development of mass produced automobiles.

What was the impact on society beyond science and technology?

The volunteer population for this study is late adolescents and young adults with ASD who have earned a learner's permit for driving, i.e. had the basic intellectual and social abilities to successfully navigate through the DMV process of passing a driving knowledge and vision test. While all children with ASD pass through this age window, not all will have the capabilities to achieve this milestone. Those who do achieve this milestone face the challenge of developing adequate skills to safely control a one-ton vehicle traveling through time and space while negotiating expected and unexpected road, signal, and traffic demands and maintaining control of both the vehicle and oneself. This is no small achievement when considering several common characteristics of ASD that impact driving: 1) difficulty with motor planning and coordination interferes with steering, accelerating, judging time and distance, braking, etc., especially when two or more of these tasks must occur simultaneously; 2) hyper-focus and limited attention flexibility/shifting compromises the ability to concentrate on keeping the car in the correct lane, maintain an appropriate distance from the lead car, and attend to the stoplight ahead, among the many other demands of driving; and 3) a desire for routine, structure, and rules presents a substantial problem when the driving routine is disrupted, e.g., when encountering a detour. The ability to earn a full driver's license opens new social, occupational, and personal opportunities and responsibilities, as well as real risks to one's own and others' physical safety. Therefore, it is paramount that these novice drivers have training in the safe operation of a car that taps their abilities while accommodating to their challenges. Virtual Reality Driving Simulation (VRDS) is capable of breaking down the complex task of driving into systematic training elements that can be progressively layered as competence is achieved, while safely exposing the trainee to both challenging and potentially dangerous situations. VRDS allows objective assessment and feedback of performance. This non-judgmental and non-emotional mode of training is an ideal fit for those with ASD, and we have demonstrated that it leads to improved driving skills of adolescents in general, as well as military personnel recovering from a traumatic brain injury and young people with ASD. We propose the first systematic, comprehensive assessment of how VRDS can be used to evaluate an individual's capability to learn how to safely drive a car and promote the learning of safe driving skills that lead to the acquisition of an independent driver's license and a subsequent low rate of driving mishaps. If this effort proves effective, it could revolutionize this developmental milestone by providing a documented, systematic, standardized education program in driving, which is generally taught by well-intended but frequently ill-prepared trainers who have to rely on emersion of a novice driver into real world driving situations that are potentially dangerous. VRDS training provides systemic training modules with a standardized training manual, so any competent trainer could provide a standardized and effective assessment and training program for any ASD individual who has achieved a learner's permit. This process of obtaining a permit and VRDS training to improve driving skills with an end goal of securing a full driver's license promotes autonomy, social contribution, and self-esteem throughout their lives. Further, this training could be made available to those ASD drivers who have acquired a driver's license but still do not feel comfortable/competent behind the wheel.

CHANGES/PROBLEMS:

Nothing to report

PRODUCTS:

Nothing to report

PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

What individuals have worked on the project?

Name:	
Daniel Cox	No Change
Ron Reeves	No change
Matt Moncrief	No change
Tim Brown	No change
Gary Gaffney	No change
Rose Schmitt	No change

Has there been a change in the active other support of the PD/PI(s) or senior/key personnel since the last reporting period?

Nothing to report

APPENDIX: 1

Virginia Driving Safety Laboratory

Novice Driver Improvement Program for Individuals on the Autism Spectrum

Assessment ($150)

The first session will be comprised of Operational ability tests and a Tactical skills test over the course of two hours.

Operational Tests

We will rate a student's driving relevant abilities as compared to a large sample of licensed drivers. Tests cover visual perception, motor reaction time, cognitive processing, and executive functioning. For example, to measure foot reaction time the driver follows a lead car at a fixed speed and distance. The lead car's brake lights come on 10 times. The driver's task is to remove their foot from the accelerator and press on the brake pedal as quickly as possible when the brake lights come on.

Tactical Test

This test is similar to an on-road exam. Students drive on virtual rural, city, and highway roads following automated instructions, while interacting with traffic and signage. Variables such as lane position and speed are continually monitored, in addition to adverse events like inappropriate braking and improper use of turn signals.

Eye-Tracking

Students wear eye-tracking glasses that record where they are looking while driving and how long they are looking at different things, like the speedometer, mirrors, or cross traffic (see photo).

Driver wearing eye tracking glasses while performing the Operational Peripheral Vision Test

One-Hour Training Sessions ($75/hr.)

Based on the student's abilities, the trainer will recommend a starting module. Training begins with learning basic driving skills, one at a time. First students learn how to maintain lane position. Once this is mastered, they move on to speed control, then braking. When they are able to perform all of these skills in concert, more complicated road sections are introduced, followed by sessions dedicated to using mirrors and turn signals and identifying hazardous situations. The final sessions introduce traffic and address how to drive defensively. The training is entirely personalized, so any content that is particularly difficult for your student can

be emphasized. Training takes between 4-12 sessions, depending on the student's initial abilities and learning speed.

Driving Anxiety

Some individuals on the spectrum get very anxious when even thinking about driving and get more anxious when they get in open traffic. This anxiety can significantly interfere with safe driving. Using a variety of stress management techniques, we address this problem directly.

Homework

Like learning any skill, such as playing the piano or shooting a basketball, the student has to practice between training sessions. This means the student has to have access to a car and someone willing to practice the skills learned in the simulator in a real car on real roads. Without this practice, simulator training will have little benefit. Similar to simulator training,

<u>Unsolicited Expression of Appreciation</u>

Much of this experience utilized the magic formula that works for our kids, breaking down a seemingly insurmountable task into small, manageable parts and giving consistent exposure. A great deal of his anxiety about driving, which is often his major roadblock to success, has resolved. Now Joe is in the best possible position to go forward with logging driving time and working towards earning his license.

My husband and I have been knocking on doors and turning over stones, sometimes methodically, and in other instances in a panic, searching for answers, solutions, and support for our child. Throughout our journey, we have found some resources to be weak and others mediocre. Then there are those connections which touch our lives so profoundly, we are struck with the realization that Joe has been given the opportunity to experience something positive for not only a moment but for a lifetime. I am happy to be able to tell you Joe's participation in the driving study has been the latter.

Of course, we gave pause when trading the driver's seat for the passenger's with our student. How much more when our teen is on the spectrum? A driving simulator gave our son experience and all of us comfort well before he had gone much beyond our driveway. We are particularly struck by the difference before the simulator work and afterwards. I no longer clench my teeth and have to stifle a gasp when passing neighborhood mailboxes, since Joe has become well aware of his road positioning. I'm sure our neighbors are grateful as well.

All staff involved with the study were extraordinarily kind, professional, and supportive, and put Joe at ease, which is not always an easy feat. During the study, we had promised to practice on-road work. Having weekly accountability kept our momentum going, and we were able to notice Joe's progress. Little by little he felt more comfortable in both the virtual and actual driver's seat. By the time Joe was due to take his practical assessment, he had lost his momentum with practice, and his self-confidence had waned. However, the lessons he learned remained, and he was able to complete the full assessment, step out of the car smiling, and hear a robust 'great job!' from his tester. There is nothing like hearing those

on-road training should use progressively more demanding roads and a supportive environment.